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GB 2010891A
GB 2005953A
GB 1299664
GB 1258902
GB 1052262
GB 633693
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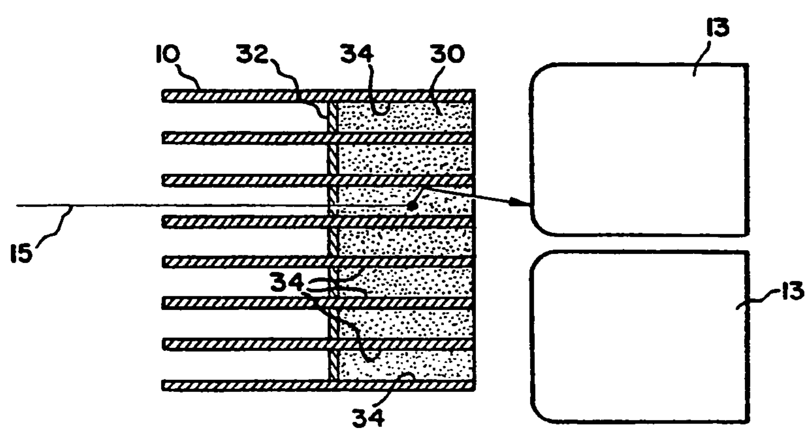
(54) Multi element, high resolution scintillator structure

(57) A gamma camera scintillator structure, suitable for detecting high energy gamma photons which, in a single scintillator camera, would require a comparatively thick scintillator crystal, so resulting in unacceptable dispersion of light photons, comprises a collimator array 10 of a high Z material with elongated, parallel wall channels with the scintillator material 30 being disposed in one end of the channels so as to form an integrated collimator/scintillator structure. The collimator channel walls are preferably coated, 34, with light reflective material and further light reflective surfaces 32, being translucent to gamma photons, may be provided in each channel. The scintillators may be single crystals or preferably comprise a phosphor dispersed in a thermosetting translucent matrix as disclosed in GB 2012800A. The light detectors of the assembled camera may be photomultiplier tubes 13, charge coupled devices or charge injection devices.

Fig. 3



The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

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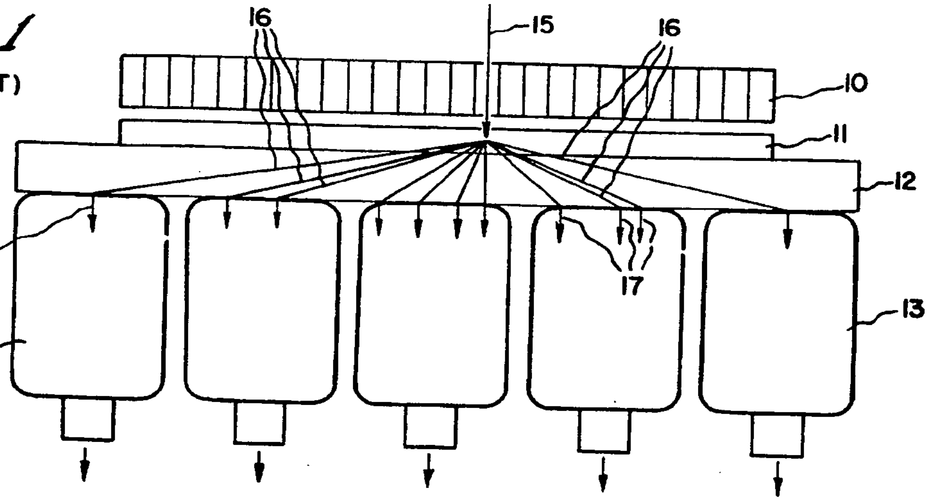
Fig. 1
(PRIOR ART)



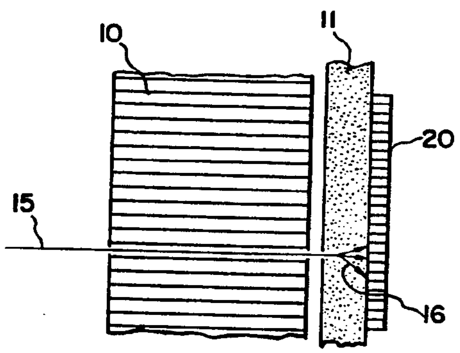


Fig. 2

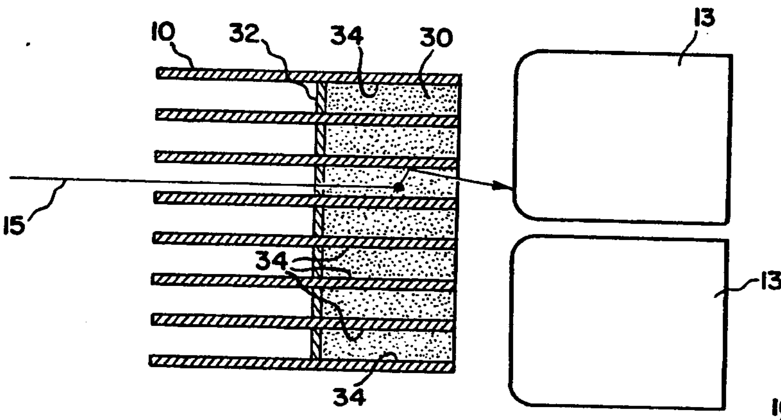
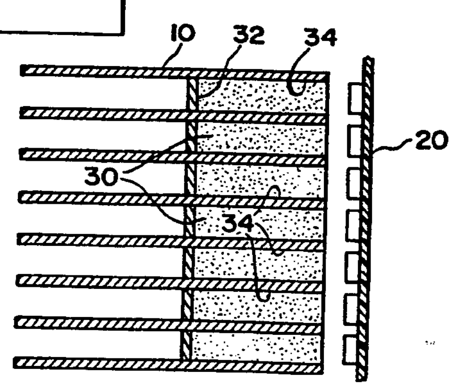


Fig. 3

Fig. 4



SPECIFICATION

Multi-element, high resolution scintillator structure

This invention relates to emissive radiography cameras, and more particularly, to collimator and scintillator structure for gamma cameras.

A gamma or Anger camera is an emission radiography device which operates by measuring radiation induced in a body, for example, a human body into which a radioactive substance such as technetium is injected. During nuclear decay of these injected radioactive substances, high energy electromagnetic photons are emitted. Such photons are referred to as gamma wavelength photons even though the photon energies (frequencies) correspond to x-ray wavelength radiation. Because the gamma photons emitted arise from the same nuclear decay process, the photons are mono-energetic. However, they become less energetic as they undergo scattering in the body and change direction. The function of the gamma camera is to spatially and temporally detect certain of these emitted gamma photons. To insure that only those photons coming from a particular direction are detected, the emitted gamma photons are passed through a collimator structure typically comprising a honeycomb array of a high Z material such as lead, tungsten, or tantalum. The collimator assures that the photons are essentially mono-directional. Thus, after the collimator eliminates those gamma photons arriving at undesired angles, the photons pass through the collimator and are made to impinge on a slab of scintillating material, For example, this slab might typically comprise a single crystal of sodium iodide with a thallium activator (NaI: T1). The impinging gamma photon is converted at an active site within the scintillator material to a plurality of longer wavelength, lower energy photons with energies typically in the visible and near-visible spectrum. These light photons radiate from the active site in a plurality of directions. Thus, if one were to observe a single one of these light photons, one could not determine the particular collimator cell through which the gamma photon passed. However, this information is obtainable by observing a number of the light photons produced. This may be accomplished, for example, by disposing a two-dimensional array of photomultiplier tubes opposite the scintillator slab so that the majority of light photons may be detected. Additionally, a light piping plate may be disposed between the photomultiplier tubes and the scintillator slab to act as a light gathering lens. The total energy in the original gamma photon is found by summing the outputs of all the photomultiplier tubes to generate a number which is proportional to the energy of the gamma photon. Knowing this energy value permits detected scintillations exhibiting energies outside of a satisfactory range (window) to be disregarded. A weighted average of the individual photomultiplier tube outputs is computed, usually by electronic analog means to determine the coordinates of the collimator cell through which the gamma photon passed. The collimator cell position coordinates, along with the time at which the scintillation occurred, is recorded for later static or dynamic display purposes.

The typical Anger camera collimator comprises approximately 10,000 individual cells arranged for example in a 100 x 100 cell rectangular array. Opposite the collimator and scintillator slab, photomultiplier tubes are disposed typically in a circular array. The photomultipliers are closely spaced to one another. Either 7, 19, 37, 61, or 91 photomultiplier tubes are typically found in present gamma camera arrangements. The scintillator plate itself is a specially prepared and continuous crystalline material, such as NaI:T1. The collimator material is typically lead, which is relatively impervious to gamma wavelengths photons so that cross-talk between nearby collimator cells is substantially eliminated.

To improve the discrimination capabilities of the gamma camera and to permit diagnoses of organs situated in the body interior, it is presently desired to increase the energy of the gamma photons from approximately 60 kev to approximately 200 kev or more. This is easily accomplished by a judicious selection of the radioisotope to be injected or otherwise employed. However, to maintain the level of quantum efficiency needed to allow energy discrimination and rejection of scattered gamma photons (and thus maintain accurate radio isotope mapping), it is necessary to increase the thickness of the scintillator slab so as to provide greater gamma photon stopping ability. However, the thicker scintillation plates produce a greater dispersion or smearing of light photons with a consequential loss in resolution instead.

Background information with respect to collimation and the general operation of gamma cameras may be found for, example, in U.S. Patent No. 4,081,687 issued March 28, 1978 to York et al.

The illustrative embodiment of the present invention discloses an integral collimator/scintillator structure which provides extremely high resolution. The resolution of the gamma camera of the present invention is limited only by the collimator material which must be thick enough to prevent cross-talk between adjacent cells, yet thin enough so as not to present a significant cross-sectional area as compared to the area presented by the cellular channels through the collimator array. In accordance with the present invention, the scintillator material fills the end of the collimator array distal from the gamma photon source. The scintillator material itself comprises an indexed matched scintillation material such as barium fluorchloridedoped with europium (BaFCl:Eu) suspended in an indexed matched substance. Such scintillating materials are disclosed in U.K. patent Specification No. 2012800. The integral structure of the present invention is suitable for use in both conventional gamma camera configurations and configurations employing charge injection devices or charge

coupled devices as detectors instead of photomultiplier tubes. In accordance with another embodiment of the present invention, the walls of the collimator channel are suitably coated with a light reflective material such as silver or magnesium oxide. Additionally, the x-ray incident side of the scintillator material within each cellular channel is coated with a low Z light reflective material so that the gamma wavelength photons penetrate easily but the light photons generated within the scintillator material are reflected toward the detector.

The collimator/scintillator assembly is preferably formed by first coating the collimator array with a reflecting material such as by electroplating with silver or by settling from solution material such as magnesium oxide or other highly reflective materials. The cellular channels are then partially filled to a height of approximately 5 millimeters with an appropriate mixture of BaFCl:Eu suspended in an indexed matched plastic monomer mixture of vinyl toluene and vinyl naphthalene along with suitable organic dyes, if desired, to serve as wavelength conversion material. Then by a process such as silver evaporation, the x-ray incident side of the scintillator material is provided with a thin reflective coating. Either diffuse or specular reflective materials are employed.

The present invention will be further described, by way of example only, with reference to the accompanying drawings in which:—

FIG. 1 is a partial cross-sectional side elevation view schematically illustrating the structure and operation of prior art gamma cameras.

FIG. 2 is a partial cross-sectional side elevation view of a gamma camera employing charge injection devices or charge coupled devices as detector elements.

FIG. 3 is a partial cross-sectional side elevation view in accordance with one embodiment of the present invention illustrating an integral collimator/scintillator structure.

FIG. 4 is similar to FIG. 3 except that charge coupled devices or charge injection devices are employed instead of photomultiplier tubes.

FIG. 1 illustrates the general structure and operation of a gamma camera. Collimator 10 acts as a prefilter to eliminate gamma photons arriving at undesirable angles. However, the gamma photon 15 arriving from a direction aligned with the walls of the cellular channels of the collimator array 10 easily passes through a strike scintillator material 11 wherein a plurality of light photons 16 are generated. These light photons preferably are passed through a light piping plate 12 which acts as a light-gathering lens so as to cause the light photons 16 to impinge upon the faces or photomultiplier tubes 13. The light photons striking the photocathode material of the photomultiplier tubes 13 generate a flow of photoelectrons 17 which current is amplified by the photomultiplier tubes which are connected to appropriate electronic circuitry to determine the precise collimator cell through which gamma photon 15 passed and therefore determine a position in the body under study from which the gamma photon was emitted. In this way, information is gathered to determine the relative distribution of radioactive material following its injection into a body under study.

The current pulses produced by photomultiplier tubes 13 are employed to produce a weighted average indicating the particular cell through which the gamma photon 15 passed and the outputs are also used to generate a value indicating the relative energy of the impinging gamma photon 15 so that only those gamma photons within a particular energy range are considered, the rest being rejected. Simultaneous pulses arising from two essentially coincident gamma photons are also rejected. However, the times at which gamma photons arrive, as measured by the pulses of output current from the photomultiplier tubes 13 are also typically stored and used to produce dynamic pictures of absorption of radioisotopic substances by a particular organ or organs under study. For example, dynamic information concerning the operation of the thyroid gland in a human body may be obtained by the intravenous introduction of a radioactive isotope of iodine.

FIG. 2 illustrates an alternative arrangement illustrating a gamma camera in which the photomultiplier tubes 13 are replaced by a solid state detector array 20. This solid state array may comprise charge injection devices or charge coupled devices which are sensitive to light output of the scintillator material 11 and produce an electrical signal in correspondence therewith. However, even with this construction which offers potentially greater resolution than the structure of FIG. 1, increasing the thickness of the scintillator slab 11 results in a greater dispersion of the light photons 16 and a resultant smearing (loss of resolution) in the desired image.

FIG. 3 illustrates a preferred embodiment of the present invention employing an integral scintillator/collimator structure. In accordance with the invention herein, collimator 10 possesses cellular channels partially filled at ends distal from the gamma photon source with scintillating material 30. The walls of the cellular channel are also advantageously coated with a light-reflective material 34. Such material may comprise silver deposited by electroplating or a more diffuse reflecting substance such as magnesium oxide deposited from solution. Reflecting surfaces 32 can be provided which are relatively transparent to gamma wavelength photons but which reflect visible wavelength photons particularly those generated in scintillation material 30. Reflecting material 32 is advantageously formed by vapour deposition of silver. However, most of the light photons generated within the scintillating material 30 are reflected from the coating on the side walls rather than from reflective material 32. For example, as is shown in FIG. 3, incident gamma ray photon 15 impinges on an active site within scintillating material 30 and is converted to a

plurality of visible wavelength photons, the path of one of which 16 is shown as it is reflected once from the wall of the array. In this way, light photons emitted from a given activation point within the scintillation material are more controllably focused rather than dispersed, thus greatly improving the resolution of the camera.

While the structure of the present invention is possible using single crystal materials such as those employable in the single scintillator slab 11 in FIGS. 1 or 2, such an embodiment is not preferred since it requires the precise machining of a large number of crystalline scintillator elements. The present invention, however, advantageously employs a phosphor such as BcFCl:Eu dispersed in an index matched translucent matrix such as is disclosed in U.K. Patent Specification No. 2012800.The BaFCl doped with Eu is suspended in an index matched plastic monomer mixture of vinyl toluene and vinyl naphthalene. (See, for example, U.K. Patent Specification No. 2012800. The mixture is used to fill the bottom of the collimator to a height of approximately 5 millimeters and is then solidified by heat treatment at approximately 150°C. However, prior to filling with the mixture, the cellular channel walls are advantageously coated with a light-reflective material such as silver or magnesium oxide. Prior to solidification, wavelength conversion phosphors may also be added to the phosphor monomer mixture. Such wavelength conversion phosphors include perylene and P-bis[2-(4 methyl-5-phenyl-oxazolyl)] benzene also known as dimethyl-POPOP. If desired, a thin low Z light-reflecting material 32 is then applied to the end of the scintillator material nearest the gamma photon source as shown in FIG. 3. These wavelength conversion phosphors are added to convert the output of primary phosphors such as BaFCl:Eu to wavelength more suitable for detection by various electronic devices such as photodiodes which are sensitive in narrow spectral regions.

FIG. 4 is an alternate embodiment of the present invention in which the detector means for the light photons comprise either an array of charge coupled devices or an array of charge injection devices 20 rather than the conventional array of photomultiplier tubes 13. Such devices convert light photons from scintillating material to an electrical signal which is analyzed in the usual fashion as described above. Such devices provide for extremely high resolution as seen in FIG. 4.

From the above, it may be appreciated that the present invention provides an extremely high resolution gamma camera in which the collimator and scintillator are provided in a single integrated structure preferably also comprising light-reflective means surrounding the scintillator material to focus and direct the light output from the structure to appropriate detector means. The integrated scintillator/collimator structure provided herein is easily and economically constructed without the need for a single expensive crystalline scintillator slab and without the need for machining crystalline scintillator elements to fit into elemental cellular collimator channels.

While this invention has been described with reference to particular embodiments and examples, other modifications and variations will occur to those skilled in the art in view of the above teachings. Accordingly, it should be understood that the appended claims are intended to cover all such modifications and variations as fall within the true spirit of the invention.

CLAIMS

1. A gamma camera scintillator structure suitable for placement between a source of gamma wavelength photons and a light detector, said structure comprising:
a collimator array of a material relatively impervious to gamma wavelength photons, said array possessing a plurality of parallel, walled channels; and scintillator material disposed within said channels, at an end of said array distal from said source.

2. A structure as claimed in claim 1 further comprising light-reflective material coating said channel walls.

3. A structure as claimed in claim 2 in which said light-reflective material comprises silver.

4. A structure as claimed in claim 2 in which said light-reflective material comprises magnesium oxide.

5. A structure as claimed in any one of the preceding claims in which the scintillator material comprises BaFCl:Eu embedded in a translucent material having substantially the same index of refraction as BaFCl:Eu.

6. A structure as claimed in any one of the preceding claims comprising a layer of light-reflective material disposed within said light channels and oriented so as to reflect light toward said light detector, said material translucent to gamma wavelength photons.

7. A gamma camera comprising an array of light detectors and the scintillator structure as claimed in any one of the preceding claims disposed between said light detectors and a source of gamma wavelength photons.

8. A camera as claimed in claim 7 in which said light detectors comprise photomultiplier tubes.

9. A camera as claimed in claim 7 in which said light detectors comprise charge coupled devices.

10. A camera as claimed in claim 7 in which light detectors comprise charge injection devices.

11. A gamma camera scintillator structure as claimed in claim 1 substantially as hereinbefore described with reference to and as illustrated in Figures 2, 3, or 4 of the drawings.

12. A gamma camera scintillator structure as claimed in claim 7 substantially as hereinbefore described in Figures 2, 3 or 4 of the accompanying drawings.

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